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# Modelling of the Contribution of Different Blended Fertilizers to Potato Production in Basketo Special Woreda, Gamo-gofa Zone, Ethiopia

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## Abstract

Potato is important for food security in developing countries such as Ethiopia. The purpose of this study is to evaluate the contribution of varied fertilizers to potato yields at Basketo Special Woreda, Gamogofa Zone, Ethiopia. To attain this objective, a generalized linear mixed model was used to differentiate the factors that affect the marketable yield of potatoes by considering variability within three replications. In addition, this study used the Kolmogorov-Smirnov test to check the goodness of fit tests of normal distribution. The collected data were analyzed using statistical software, SAS version 9.4. The mean of plant tallness, number of plants per plot, number of plants per slope, and number of tubers per slope were 73.65 (SD = 12.2), 155.2 (SD = 112.2), 3.23 (SD = 1.31), and 10.91 (SD = 3.15.2), respectively. The result reveals that 6% of variation existed in potato yield between plots, and the remaining 94% existed within plots. Apart from a linear mixed model, a random intercept model was applied to this data. The findings reveal that fertilizer types, number of plants per plot, and numbers of tubers per hill were significant at 5% level of significant. Thus, the expected marketable yield of potatoes decreased by 0.7819 tons/hectare when the number of tubers per hill increased by 1 unit. On the other hand, the expected marketable yield of potatoes has increased by 0.0175 tons/hectare when the number of plants per plot increased by 1 unit.

## Keywords

Marketable yield; Potato; Fertilizer types; Random Intercept Model; Ethiopia

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## Introduction

The potato (*Solanum tuberosum*) is an Andean staple meal crop (Rodríguez *et al*., 2010). Potato is basically produced in Europe and North America. It is the most important meal crop and is used for food intake (Sonnewald *et al*., 2015). It has significant value in terms of food security in developing countries like Ethiopia (Girma *et al*., 2020). For instance, farmers in Ethiopia produced potatoes from 0.5 million tons in 2006 to 3.6 million tons in 2016 (Voora, Larrea and Bermudez, 2020). It has widely been grown in the highlands of Ethiopia. However, the yield of potatoes is low due to improperly used fertilizers (Alemayehu and Jemberie, 2018).

Potato production requires fertilizers like phosphorus (P). Though phosphorus (P), an important nutrient for potato production, is required in excess quantities, potatoes make inefficient use of soil phosphorus (Rosen *et al*., 2014). In addition, farmers used nitrogen fertilizer to maximize tuber size (Rens *et al*., 2018). Sulphur fertilizer is also important for increasing shoot and root interiors (Hawkesford and De Kok, 2006). Additionally, sulphur absorption is used for coordination with carbon and nitrogen pathways (Hawkesford and De Kok, 2006).

Many research findings on potato production in Ethiopia have focused on the impact of integrated application of organic and blended mineral fertilizers on potato productivity. For example, a study revealed the impact of natural and inorganic fertilizer application at the potato surrender (Girma *et al*., 2020). Similarly, an investigation by Girma, Beyene and Biazin (2017, pp.1 & 6) confirmed the influence of phosphorus and potassium fertilizers on potato growth and yield. Another study claimed the reaction of potato to nitrogen and phosphorus (Setu, Dechassa and Alemayehu, 2018). Moreover, another study disclosed the impact of fertilization administration at the trim execution and chemical composition of potato cultivated in Greece (Sebnie, Esubalew and Mengesha, 2021). Most studies have been done on to improve potato production. However, none of them show the effect of fertilizer types within and between plots. Therefore, this study is conducted in assessing the contribution of different blended fertilizers to potato production as fertilizers can have an impact on the environment and production (Briefs, 2019). In doing so, the study used conditional residual plots and Kolmogorov–Smirnov test to check the normality of the error term and goodness of fit, respectively (Massey Jr, 1951; Wang *et al*., 2018). In addition, in this study, generalized linear mixed models were used to assess the contribution of different blended fertilizer types to potato production and estimate the variation of potato yield within and between plots in the Basketo Special Woreda, Gamogofa Zone, Ethiopia.

## Study Design and Methods

*Study Area*

The field experiment was carried out at Arba Minch Agricultural Research Center, in the Southern Regional State of Ethiopia, during the 2018 and 2019 cropping seasons. Basketo Special Woreda is located in the Gamo-gofa Zone, Ethiopia. It lies at the latitude of 6.25° and a longitude of 36.58333°, with GPS coordinates of 6° 15′ North and 36° 35′ East.

*Experiment Instruments*

The potato variety named as "Belete" was planted and harvested by Holeta Rural Investigators and was utilized for the experiment (Tessema, Mohammed and Abebe, 2020). Fertilizers were applied on the sides of potato tubers on the edges. Phosphorus, sulphur, potassium, and boron nutrients were applied at the planting time; nitrogen was applied in split halves during planting and after planting. Potassium chloride (KCl), triple super phosphate (TSP), nitrogen, phosphorus, sulphur and boron (NPSB), and nitrogen, phosphorus, and sulphur (NPS) fertilizers were the nutrient sources.

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The field test was laid out at random and consisted of five chemicals with three replicates each. The trial was conducted during the autumn season in 2018 and 2019. Potato tubers were planted in a 30 cm gap with 75 cm row spacing. This study used 15 total plots with a 3.9 m by 3.75 m unit size of the plot area, and each accommodated 5 rows and 13 columns. The distance between and inside a plot was 1 m and 1.5 m, respectively.

The experimental crop variety was an improved variety (Belete). Soil samples (0–20 cm depth) before and after sowing were taken randomly in a zig zag pattern from 10 soil cores at the same depth of 0–20 cm. The soil samples were combined to form a composite 1 kg soil sample in a sterilized soil bag. Soil drying was accomplished by spreading each sample on neat paper to air dry at room temperature, then bagging and freezing for shipping. Analyses of pH, OC TN, P, K, S, and texture parameters of soil samples were analyzed within two weeks. The sample field was laid out in a randomized complete block design having five treatments: NP (165:195), NPS (120:92:17), NPSZnB (120:92:20.06:5.89:0.66), NPKSZnB (120:92:52.17: 19.74:6.06:0.88), and control (no fertilizer used) based on agricultural transformation agency's recommendation (Bellete, 2015). The agricultural transformation agency recommends that farmers apply a high amount of NP as compared to other treatments in Baskato Woreda. The first and second-year experiments were undertaken in the main rainy season (Belg from March to May) in 2018 and 2019.

*Experiment Procedures and Data Collection*

This study is based on an imminent cohort study design using field tests. It is important to connect the sides of potato tubers and secure them with soil to maintain a strategic distance. The suggested rates of P, S, K, Zn and B supplements are used as the chemicals to connect planting, while N is connected in part at half planting and the remaining half after planting was used for almost 21 days. Moreover, in the area, NPSB, NPS, and KCl fertilizers were utilized as supplements (Bellete, 2015).

Surface soil test samples (8 cores at 0–20 cm depth) were taken arbitrarily from the field before the start of the field experiment. The soil tests were composited and arranged for examinations of the soil's physical-chemical properties. Ph (6.08), OC (2.6%), OM (4.6%), TN (0.23%), available P (6.5 mg/l), and soil textural classes were clay loam for the selected farm fields at the soil laboratory of Arba Minch Agricultural Research Center, and Southern Agricultural Institute. A simple random sampling technique was used for plant selection having five plants. The authors counted the whole number of plants per plot, plants per hill, and tubers per hill, and measured the plant height of selected plants. Besides, this study estimated the marketable yield per plot and recorded it by excluding the border row.

*Quality of Data Collection*

The quality of the data was approved by information controllers who were assigned from the Arba Minch Agricultural Research Center. The information extraction apparatuses and the completeness of the information were controlled by the Arba Minch Agricultural Research Centre. All necessary amendments were made to the ultimate information collection sheet.

*Study Variables*

The indicator factors were fertilizer sort, number of plants per plot, number of tubers per slope, and plant stature. In addition, the marketable yield of potatoes was the outcome variable of the study.

*Statistical Methods of Analysis for Repeated Data*

This study used generalized linear mixed models, which are a natural outgrowth of both linear mixed models and generalized linear models. The generalized linear mixed model can be measured repeatedly over time and observed within a hierarchical trend. The generalized direct blend trend can be effectively adjusted to circumstances where different results are observed. The generalized straight-blend show expects that each result and the univariate models are combined through the detail of dispersion for all arbitrary impacts.

Besides, the blended show can be connected with the detail of negligible dispersion, which is conditional on connected arbitrary impact. Most extreme probabilities and variations are standard for both straight blended models and generalized direct models. This study summarized the effect of fertilizers by utilizing graphic insights such as cruel and standard deviation for ceaseless factors. The generalized straight blend models and model selection criteria were utilized to choose the best-fit models. Akaki Information Criteria (AIC) and Bayesian Information Criteria (BIC) were used for model comparison at a 5% level of significance (Hox, Moerbeek and Van de Schoot, 2017; Pongsapukdee and Sukgumphaphan, 2007). Finally, the indicator and reaction factors were imperative for checking the fittingness of the interface (Hosmer Jr., Lemeshow and Sturdivant, 2013).

*Model Diagnosis Checking*

Residual plots and the Kolmogorov-Simonov test were used for model diagnosis. The residual plots are the best tool for examining whether the selected model meets the normality assumption of the error term or not. A conditional residual plot is important to know the difference between the conditional fits and the observed values in the sample data. Additionally, Kolmogorov–Smirnov test was used to check goodness of fit (Massey Jr, 1951; Wang *et al*., 2018).

## Results

As illustrated in table 1, the mean and standard deviation of the marketable yield of potatoes at the first, second, and third replications of no fertilizer used are (11, SD = 6), (17, SD = 9), and (9, SD = 3) tons per hectare, respectively. In addition, the mean and standard deviation of the marketable yield of potatoes at the first, second, and third replications of NP fertilizer used are (25, SD = 10), (19, SD = 4), and (16, SD = 11) tons per hectare, respectively. Furthermore, the mean and standard deviation of the marketable yield of potatoes at the first, second, and third replications of the NP, S, Zn and B fertilizer used were (25, SD = 6), (23, SD = 7), and (21, SD = 3) tons per hectare, respectively. Therefore, it is possible to conclude that the most important fertilizers obtaining a higher yield of potatoes were N, P, S, Zn, B and NP.

Table 1: Summary Statistics for Marketable Yield within Replication

| *Independent Variables* | | *Marketable yields (ton/ha)* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Replication of the experiments* | | | | | |
| | | *First* | | *Second* | | *Third* | |
| | | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| Treatments | No Fertilizer | 11 | 6 | 17 | 9 | 9 | 3 |
| | NP 165, 195 | 25 | 10 | 19 | 4 | 16 | 11 |
| | NPS 120, 92, 17 | 19 | 3 | 19 | 9 | 23 | 3 |
| | NPSZnB 120, 92, 20.06, 5.89, 0.66 | 25 | 6 | 23 | 7 | 21 | 3 |
| | NPKSZnB 120, 92, 52.17, 19.74, 6.06, 0.88 | 24 | 7 | 20 | 0 | 21 | 4 |

Table 2 indicates the mean for plant stature, plants per plot, plants per slope, tubers per hill, and marketable yields, which are 73.65 (SD = 12.2), 155.2 (SD = 112.2), 3.23 (SD = 1.31), and 10.91 (SD = 3.15.2), respectively. However, the overall mean of the marketable yield of potatoes is 19.47 (SD = 7.18) tons per hectare. A line graph visualized the relationship between the marketable yield of potatoes and fertilizer types within each replication. It shows the pattern of potato yield measurements over time and the overall individual plots. It is evident from Figure 1 that the variation within and between plots increased slightly with each replication across the plots. The yield of potatoes is slightly turned down when the farmers use NP, NPS, and NPSZnB throughout the first, second, and third replications, respectively.

Table 2: Summary statistics for covariates included in this Study

| *Covariates* | *N* | *Minimum* | *Maximum* | *Mean* | *Std. Deviation* |
|---|---|---|---|---|---|
| Plant height (cm) | 43 | 51 | 99 | 73.65 | 12.200 |
| Number of plants per plot (count) | 43 | 12 | 383 | 155.23 | 112.227 |
| Number of plants per hill (count) | 43 | 1 | 6 | 3.23 | 1.306 |
| Number of tubers per hill (count) | 43 | 4 | 17 | 10.91 | 3.146 |
| Marketable yields (ton/ha) | 43 | 6 | 36 | 19.47 | 7.182 |
| Valid N (list wise) | 43 | | | | |

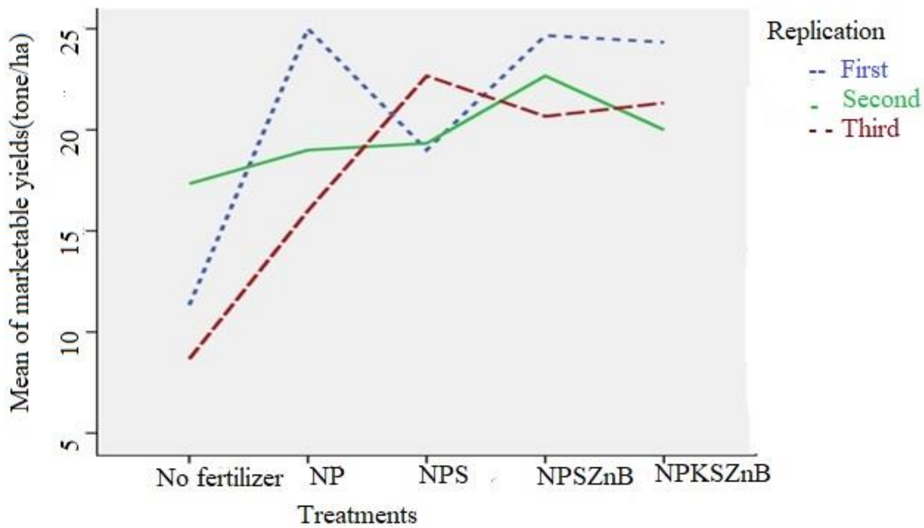


Figure 1: Line graph of marketable yield of potato for each fertilizer

The residual diagnostics of the fitted model for the distinction between standardization and scaling of residuals is shown in figure 2. The conditional residual plots require iterative influence analysis or a profiled residual variance and the residuals and the fitted values confirm linearity without distinct patterns (see Figure 2a, and 2d), i.e., constant variance. The quantile-normal plot approves the normality of errors; residual points follow the straight dashed line (Figure 2b and 2c). On the other hand, since the study used the Kolmogorov-Smirnov test for goodness of fit tests, it shows normality with a p-value equal to 0.150.

Table 3 indicates that the random intercept model is well fitted to the data, which has a small AIC, BIC and generalized Chi-square/df values. Hence, this study used a random intercept model to estimate parameters of the associated factors towards potato yields in Basketo Special Woreda, Gamogofa Zone, Ethiopia. The table 4 portrays the intra-class relationship, and it was found to be (1.4792/1.4792+23.3129) = 0.05992. 6% of the variation in the marketable yield of potatoes existed between plots, and the remaining 94% inside plots.

In this manner, it appears that the attractive abdicate of potato generation is decided by fertilizer combination or types, the number of plants per plot, and the number of tubers per slope covariates. From table 5, considering fertilizer types as a predictor variable, compared to no fertilizer used for the production of potatoes, the expected marketable yield of potatoes has a difference between NP fertilizer used and no fertilizer used, as it was about 10.3470 tons per hectare; the difference between NPS fertilizer used and not used was 10.9949 tons per hectare. In addition, the difference between NPSZnB fertilizer used and not used

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was 13.5530 tons per hectare. Moreover, the variance between NPKSZnB fertilizer used and not used was 13.0592 tons per hectare per replication, as the result indicates.

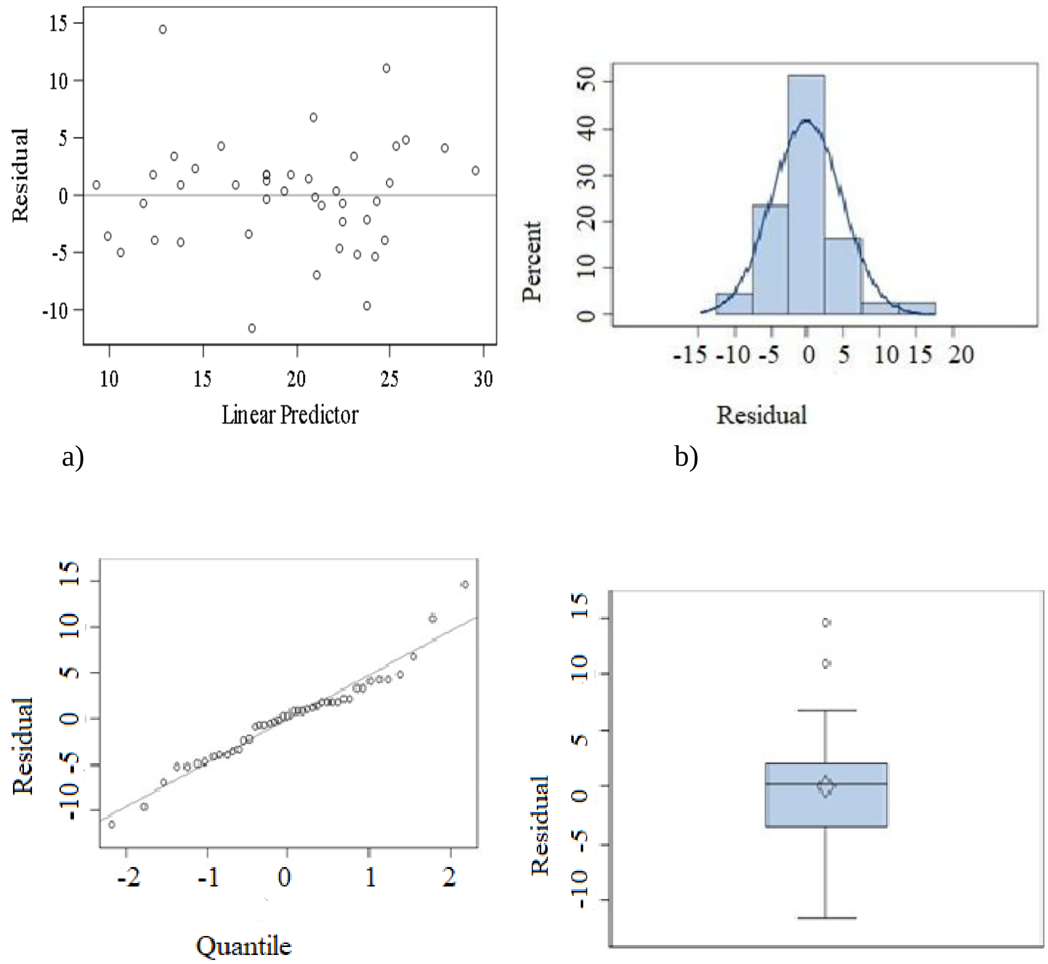


Figure 2: Conditional Residual Plots for Model Diagnosis Checking

Table 3: Model Selection

| *Random effects* | *AIC* | *BIC* | *Generalized Chi-Square / df* |
|---|---|---|---|
| Intercept only model | 296.5 | 293.7 | 50.2 |
| Random intercept model | 281.4 | 271.5 | 23.31 |
| Random coefficients model | 291.5 | 286.1 | 38.9 |

Table 4: Estimation of Covariance Parameter for the Marketable Yield of Potato

| *Covariance Parameters* | *Subject* | *Estimate* | *Standard Error* |
|---|---|---|---|
| Variance | Replication | 1.4792 | 2.7055 |
| AR (1) | Replication | 0 | |
| Residual | | 23.3129 | 5.2341 |

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In other words, the marketable yield of potato changes for each NP fertilizer used was 10.347 times that of the non-fertilizer used in each replication. When NPS fertilizer was used in each replication, the marketable yield of potatoes was 10.9949 times greater than when no fertilizer was used. Additionally, the marketable yield of potatoes for NPSZnB in each replication was 13.55 times that of the amount of fertilizer not used. In expansion, the rate of change of the marketable yield of potatoes for NPKSZnB in each replication was 13.0592 times higher than without including fertilizer used to keep the other factors consistent. This clearly shows that the expected marketable yield of potatoes is increased by 0.0175 tons per hectare when the number of plants per plot is increased by 1 unit. However, the potato yields are decreased by 0.7819 tons/hectare when the number of tubers per slope was increased by 1 unit.

Table 5: Parameter Estimation of Random Intercept Model

| *Variables* | *levels* | *Estimate* | *SE* | *P-value* | *95% CI* | |
|---|---|---|---|---|---|---|
| Intercept | Constant | 19.1100 | 5.7302 | 0.0794 | -5.5449 | 43.7649 |
| Treatments | NPKSZnB | 13.0592 | 2.9009 | <.0001 | 7.1572 | 18.9612 |
| | NP | 10.3470 | 2.6864 | 0.0005 | 4.8814 | 15.8126 |
| | NPS | 10.9949 | 2.7339 | 0.0003 | 5.4328 | 16.5570 |
| | NPSZnB | 13.5530 | 2.7840 | <.0001 | 7.8890 | 19.2170 |
| | Not used | 0 | . | . | . | . |
| Plant height (cm) | Continues | -0.04529 | 0.09712 | 0.6440 | -0.2429 | 0.1523 |
| Number of plants per plot | Count | 0.01750 | 0.007500 | 0.0259 | 0.002242 | 0.03276 |
| Number of tubers per hill | Count | -0.7819 | 0.3664 | 0.0404 | -1.5274 | -0.03646 |

## Discussion

The random intercepts model shows that the attractive abdicate of potato generation is decided by fertilizer sorts, the number of plants per plot, and the number of tubers per slope covariates. Additionally, 6% of the variation in the marketable yield of potatoes existed between plots, and the remaining 94% of the variety existed inside plots. This finding shows that the fertilizer type and rate were significantly associated with the marketable yield of potatoes. The productivity of potatoes in Ethiopia is very low due to improper use of fertilizer. Potatoes are the most important crops for both cash and food security in developing countries like Ethiopia. This result was confirmed by a study done in Ethiopia (Chindi *et al*., 2017; Oumer, Hjortsø and de Neergaard, 2013).

This study shows the effect of proper use of fertilizer types on reducing the unmarketable yield of potatoes by increasing the marketable yield of potatoes. The marketable yields of potatoes are increased by 10.3470, 10.9949, 13.5530, and 13.0592 tons per hectare when the farmer used NP, NPS, NPSZnB, and NPKSZnB fertilizer types, respectively. These results are in agreement with the study carried out by various researchers (Al-Taey, Al-Naely and Kshash, 2019). Based on the study done in Russia, Zewide, Singh and Kassa (2021) stated that the application of a combination of 75% of mineral NP can significantly increase the tuber yield. The finding that was reported in Egypt showed significant increases in the total and marketable yield of potato crops from plots treated with 50% of the recommended mineral fertilizers (El-Sayed, Hassan and El-Mogy, 2015). These results also coincide with the study done in Egypt by Ali *et al.* (2022) showing that the increase in the total yield of tubers may be due to the increase in the number of tubers, promoting nutrient uptake and enhancing plant growth through its ability to produce plant hormones as a result of blended or combined fertilizers. Generally, the overall finding indicates that the marketable yield of potatoes increased by 0.0175 tons per hectare when the number of plants per plot increases by 1 unit. Similar findings are conveyed by other researchers (Manea, Al-Bayati and Al-Taey, 2019; Shahnazari *et al*., 2007). In addition,

the marketable yield of potatoes increased by 0.7819 tons/hectare when the number of tubers per hill decreases by 1 unit. Similar results are reported by other scholars (Al-Taey, Al-Naely and Kshash, 2019). The study was done on the relationship between total yield, and the number of tubers in potato crops, and shows the yield of large tubers is linearly related to total yield and the number of tubers; but where tubers are graded by size, the relationship varies with tuber shape. The main mechanisms available to growers for altering the number of tubers is varietal choice and seed rate but these are also likely to alter total yield with an unpredictable net effect (Burstall, Thomas and Allen, 1987).

## Conclusion

Enhanced farm productivity is basic to food security and reducing poverty in developing countries, including Ethiopia. The purpose of this study is to evaluate the contribution of varied fertilizers to potato yields at Basketo Special Woreda, Gamogofa Zone, Ethiopia. To address this objective, a generalized linear mixed model was used to differentiate the factors that affect the marketable yield of potatoes by considering variability within, and between plots. The random intercept model is well fitted to this data, and it shows fertilizer types, number of plants per plot, and number of tubers per hill was significant at 5% level of significance. The expected marketable yield of potatoes increased by 0.7819 when the number of tubers per hill increased by 1 unit. Additionally, the expected marketable yield of potatoes increased by 0.0175 tons per hectare when the number of plants per plot increased by 1 unit. The result of this study suggests that the Ethiopian agriculture authorities should encourage farmers to use NP, NPS, NPSZnB, and NPKSZnB fertilizer types. The total yield of tubers increased may be due to the increase in the number of tubers, promoting nutrient uptake and enhancing plant growth through its ability to produce plant hormones or soil quality. Therefore, the variation of the marketable yield of potatoes within plots was higher than between plots due to the quality of the soil and quantity of fertilizers.

Hence, potato productivity of farmers is basic in food security and reduces poverty. Therefore, government and non-governmental organizations as well as other stakeholders should provide awareness to the farmers for fertilizers rate and potato production. The researchers should also give attention to compare NP, NPS, NPSZnB, and NPKSZnB fertilizers with natural fertilizers, seasonal variation and potato varieties.

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## Authors' Declarations and Essential Ethical Compliances

*Authors' Contributions (in accordance with ICMJE criteria for authorship)*

| Contribution | Author 1 | Author 2 | Author 3 | Author 4 | Author 5 |
|---|---|---|---|---|---|
| Conceived and designed the research or analysis | Yes | No | Yes | No | No |
| Data collection | Yes | Yes | No | No | Yes |
| Contributed to data analysis & interpretation | No | No | Yes | No | No |
| Written the article/paper | Yes | No | Yes | Yes | No |
| Critical revision of the article/paper | Yes | No | Yes | Yes | No |
| Editing of the article/paper | Yes | No | Yes | Yes | No |
| Supervision | Yes | No | Yes | Yes | No |
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| Funding Acquisition | No | No | No | No | No |
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*Research involving human bodies (Helsinki Declaration)*
Has this research used human subjects for experimentation? No

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*Research involving Plants*
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